

REMARKS

Examiner Kielin is thanked for his ongoing and careful examination of the subject Patent Application. Claim 1 has been amended based on a careful review of Examiner's rejections and claim 3 was canceled in response to Examiner's objection.

Briefly, Applicant wishes to point out the major features of his invention. One major problem associated with the formation of damascenes is chemical mechanical planarization (CMP) because the complete removal by CMP of metal film on silicon oxide (SiO₂) is extremely difficult. One method of eliminating copper (Cu) or aluminum (Al) on silicon oxide is by overpolishing, however, dishing then appears which erodes the metal lines beyond what is acceptable. In this invention, a reverse tone photo mask is proposed which covers the damascene area and which totally removes the Cu or Al from the silicon oxide through reverse etching. When the Cu or Al on the silicon oxide is etched off, those areas of the wafer not covered by the photoresist are free of redundant metal (copper, aluminum, etc.). As a result, the reduced polishing decreases erosion and dishing of the metal lines.

Page 4, line 4 of the specifications was amended to correct a wrong US Patent No. The correct number is 4,702,792.

2. Applicant asks for reconsideration of the objection to the specification because of informalities on page 5, line 8. The informalities were corrected as called for by the Examiner in our reply filed 4/27/00, paper no. 4, page 2 and page 5, item 2.

3. Reconsideration of the objection of Claims 3 under CFR 1.75 as being a substantial duplicate of claim 1 is requested, in light of the following arguments.

Claim 3 has been canceled and, therefore, the rejection is moot.

5. Reconsideration of the rejection of Claims 1-9 under 35 U.S.C. 103(a) as being unpatentable over Avanzino et al. (US 4,954,459) in view of Datta et al. (US 5,567,300) is requested, in light of the following arguments.

Claim 1 was amended to more clearly spell out Applicant's invention by adding that the barrier metal layer -- in addition to the copper layer -- not covered by photoresist is etched away, in agreement with the specifications, page 7, second paragraph. This modification makes it clear that in Applicant's method one etching step removes all material (copper layer 18 as well as barrier metal layer 16) from areas 20 down to the silicon oxide layer 10. After the photoresist is stripped, the remaining

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copper dual damascene layer 18 and barrier metal layer 16 are planarized, page 9, last paragraph.

Examiner asserts that Avanzino et al. discloses the same method as Applicant's invention, both

*"forming a reverse tone photoresist mask which covers
trenches but leave exposed elevate regions, .."*

and

*".. removing at least a portion of the elevated regions by
etching .."*

The last step only applies to Avanzino because Applicant's method has the step of "etching away that part of said copper layer and said barrier metal layer not covered by said reverse tone photoresist ..", i.e., Applicant etches all the way down to the silicon oxide layer 10. Compare Avanzino's FIG. 6 with Applicant's FIGs. 2e and 3d.

Avanzino then planarizes to level 30" (FIGs. 7 and 8). This causes no dishing problems in Avanzino's case because he has a wafer with a uniform silicon oxide surface. But planarizing a wafer coated with a metal, such as copper, down to the silicon oxide is exactly what Applicant wants to avoid because it would invariably lead to dishing of the damascene trenches.

Following Avanzino's method in more detail reveals that Applicant's methods differ from Avanzino because Avanzino first etches down to X_2 (col 7, line 33):

"..in FIG. 6, the exposed portions of conformal oxide layer 30 are now etched down to the level of the unexposed portions of oxide layer 30, i.e., down to about the level X_2 , .."

and after removing of the photoresist (col 7, line 61):

".. leaving the structure shown in FIG. 7 with remaining conformal oxide layer 30' shown with raised portions 30a-30d remaining .."

Avanzino then polishes the structure (col 8, line 12):

"This polishing step is carried out until the high oxide portions 30a-30d of underlying conformal oxide layer 30' are removed, leaving a highly planarized surface 30" , as shown in FIG. 8 which may be about the level X_3 shown in FIG. 4, ..

To achieve the surface as shown in FIG. 9, Avanzino proposes additional etching (col 8, line 35):

"Alternatively, oxide layer 30" may be further etched to expose the adjoining active regions of the substrate, leaving oxide portions 30e-30g remaining in between the exposed portions of substrate 2, as shown in FIG. 9. .."

However, as Avanzino explains further on, subsequent etching is problematic without the protection of a mask to avoid inadvertent etching of the silicon substrate. If this last etching step without a mask is problematic for Avanzino's silicon substrate it is just as problematic or more so for Applicant's copper damascene structure.

Referring again to the polishing step recited above (col 8, line 12): if that step were applied to Applicant's damascene structure, the polishing process would apply the same pressure to the softer damascene copper trenches as it would to the now exposed and much harder silicon oxide, resulting in dishing of the copper damascene trenches. This is precisely what Applicant is trying to avoid and why Applicant has proposed his present invention.

An examination of Avanzino's method discloses that his only concern is a uniformly planarized surface of silicon oxide 30 as illustrated in the sequence from FIG. 3 through FIG. 8. He achieves this through photoresist and etching (FIG. 5 and FIG. 6), removal of the photoresist and polishing of the silicon oxide (FIGs 6-8), and a final polishing if the silicon oxide is to be totally removed from the substrate 2 surface (FIG. 9). Presumably Avanzino is not concerned about dishing because dishing is not a problem for silicon oxide trenches (field oxide) in a silicon substrate.

By contrast, dishing is the overriding problem in Applicant's planarizing of copper damascene and Applicant, therefore, could not use the method proposed by Avanzino.

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As a result Applicant has sought new ways to correct this pressing problem. Applicant believes that he has not only found a better way to planarize copper damascene but also a much more cost effective way. Applicant trusts that the foregoing explanations convince the Examiner that Applicant's claims 1-9 are not obvious over Avanzino and, therefore, allowable.

Regarding Examiner's assertion "*that sealing a copper layer with a capping layer after planarization is well known in the art*", Applicant wishes to point out, as argued above and in our reply filed 4/2700 in paper no. 4, that independent claims 1 and 5 are now believed patentable, therefore, any part of independent claims 1 and 5 is also believed patentable.

6. Reconsideration of the rejection of Claims 4 and 9 under 35 U.S.C. 103(a) as being unpatentable over Avanzino et al. (US 4,954,459) in view of Datta et al. (US 5,567,300) is requested, in light of the following arguments.

As argued under 5. above, independent claims 1 and 5 are believed patentable, therefore, dependent claims 4 and 9 are also believed patentable.

7. The Examiner is thanked for his indication of allowability of Claims 10 to 12.

8. Avanzino's method does not work for the application contemplated by Applicant because Avanzino etches away the elevated silicon oxide areas to create – after the PR removal – a wafer with a nearly uniformly high surface of silicon oxide which covers the wafer. Polishing (planarizing) that silicon oxide surface to remove non-uniformities 30a-30d of FIG. 7 is not a problem. By contrast, Applicant has – after the initial etching and PR removal – a wafer surface comprised of silicon oxide areas interspersed with areas of damascene metallization per FIGs. 2f or 3e, i.e., areas which differ markedly in hardness. Because areas 20 are now free of metal 18, the reduced polishing achieves a flat, non-dished surface.

Were Applicant to follow Avanzino's method and only partially etch away the metal in area 20, FIGs. 2e and 3d, increased polishing still would be required and Applicant would wind up with the dished surface of the prior art (FIG. 1c).

While FIGs. 3 and 5 of Avanzino are like FIGs. 2c and 2d of the invention, FIGs. 6-8 of Avanzino and FIGs. 2e-2g of the invention differ for the foregoing reasons. FIG. 9 and FIG. 2h are the same but they have been arrived at in totally different ways, as was explained under item 5 above.

All claims are now believed to be allowable.

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It is requested that should Examiner Kielin not find that the Claims are now Allowable that he please call the undersigned attorney at (914) 452-5863, to overcome any problems preventing allowance.

Respectfully submitted,

A handwritten signature in black ink, appearing to read 'S. B. Ackerman', with a long horizontal flourish extending to the right.

Stephen B. Ackerman, Reg # 37,761